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COMMONWEALTH OF AUSTRALIA.

PATENT SPECIFICATION

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Application Lodged (No. 41,119/58)..........3rd September, 1958.

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Classification 07.8.

International Classification G 21.

Drawings (2 sheets) attached.

COMPLETE SPECIFICATION.

"IMPROVEMENTS IN NUCLEAR REACTORS."

The following statement is a full description of this invention, including the best method of performing it known to us:-

This invention relates to nuclear reactors of the kind having a core disposed in a closed vessel and including a body of moderating material formed with fuel channels and having a bottom support. It has previously been proposed to centre the body of moderating material including in the core of a gas cooled nuclear reactor within a pressure vessel by keying the body adjacent the centre thereof to the core supporting means. Such a construction, however, is suitable only when the nuclear reactor is stationary and an object of the invention is the provision of an improved form of core restraint suitable for use when the core may have imparted thereto tilting movements. More particularly, an object of the invention is the provision of a nuclear reactor having a form of core restraint suitable for use when the reactor forms part of ship propulsion plant.

The present invention provides a nuclear reactor

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of the kind having a core disposed within a closed vessel and including a body of moderating material formed with fuel chan and having a bottom support, wherein lateral supports are arr to position the body laterally within the vessel, the latteral supports acting between the body and the vessel and being adap to permit differential thermal expansion and contraction betwe the body and the vessel.

In one embodiment of the invention, the fuel channel are upright and the body is constrained at its sides by a circur ferentially sectionalised support wall surrounding the body, adjacent sections of the wall are coupled together by compens means adapted to ensure that the constraining action of the wall on the body is maintained notwithstanding differential ther expansion and contraction of the body, and the wall and the lat supports act on the body through the support wall.

By way of example, embodiments of the invention w now be described with reference to the accompanying partly di grammatic drawings in which:-

Figure 1 is a vertical section on the line I-I of Figu 2 of a reactor installed in a ship;

Figure 2 is, rather more diagrammatically, a secti on the line II-II of Figure 1;

Figure 3 is a detail of Figure 2 shown on an enlarge scale;

Figure 4 is a further detail on an enlarged scale of Figure 2; and

Figure 5 is an alternative to the detail shown in Figure 3 on the same scale.

The reactor includes the pressure vessel 1 mounted the concrete biological shield 2 by means of the webs 3 welded to the outer surface of the cylindrical part of the vessel 1. T webs 3 are re-inforced by the brackets 4 and project into slots 5, lined with steel 6, in the biological shield 2.

The core comprises the graphite body or stack 7. body 7 is twelve-sided and is supported from beneath in a kno manner by the diagrid 8. The diagrid 8 rests on the brackets 9 and is prevented from moving upwardly by the brackets 10, the brackets 9 and 10 being welded to the inner surface of the vessel 1.

The body 7 is of known construction and comprises graphite bricks of square horizontal cross-section and a heigh which is large compared with their breadth. Control rod cha and fuel channels which are indicated generally by their axes and 11a respectively extend throughout the height of the body 7 The fuel channels 11a are arranged in clusters of sixteen aro a central control rod channel in known manner. The body 7 i cooled by carbon dioxide at a pressure of about 400 p.s.i. admitted through the inlet ducts 12 and withdrawn through the

outlet ducts 13 and a heavy plate 14 is provided on the top of the body 7 to prevent the uppermost blocks from being dislodged by the passage of carbon dioxide.

The body 7 is surrounded by a sectionalized wall comprising angle plates 15 connected together by the compensating links 16. The wall is arranged to be affected by the heat developed during the operation of the reactor in such a way that its inner periphery is always the same as the outer periphery of the body 7 regardless of the temperature.

Each plate 15 comprises the limbs 15a and 15b and there are three plates 15 mounted one above another at every alternate apex of the body 7. The limbs 15a and 15b are each nearly as long as the width of a side of the body 7 and meet along a vertical line.

An outwardly extending apertured boss 17 is formed at the centre of each plate 15 and the plates 15 are each reinforced by the medial ribs 18, the outer ribs 19 and the pairs of ribs 20 extending above and below, and parallel to, each rib 18 and serving as brackets to which the compensating links 16 are connected by pivot pins 16a.

Each plate 15 co-operates, through its boss 17, with a tubular support extending through the biological shield 2 and indicated generally by 21. One support 21 is shown partly cut away in Figure 2 and is shown in detailed section on a larger scale in Figure 3, in the condition appropriate to the reactor being cold.

The tubular support 21 comprises a cylinder 22 welded at its inner end to the periphery 23 of an aperture in the pressure vessel 1, the aperture lying opposite the boss 17. A piston 24 is arranged to slide within the cylinder 22. Its outer end projects slightly beyond the end of the cylinder 22 and the space between the cylinder 22 and the piston 24 is closed by the piston rings 25. The major part of the space within the piston 24 is filled with shielding material 26 and the walls of both the cylinder 22 and the piston 24 diverge outwardly at 27 and 28 respectively to ensure that there is no direct path along which radiation can escape from the core. The inner end of the gap between the cylinder 22 and the shield 2 is closed to radiation by the shielding collar 29.

The inner end of the piston 24 is connected to the boss 17 of the plate 15 by means of the ball-headed member 30 screwed into the end of the piston 24 from the inside of the plate 15 before the bricks of the body 7 have been placed in position. The member 30 is screwed home until the ball portion 31 rests against the seat on a flange 32 projecting inwardly from the outer end of the boss 17. A member 33 having a seat against which the innermost part of the surface of the ball portion 31 rests is then screwed into position from the inside of the plate 15. It

will be seen that this connection is such that whilst allowing the axis of the piston 24 to oscillate relatively to the plate 15, the plate 15 and piston 24 are constrained to move together in the direction of the axis of the boss 17.

The outer end of the cylinder 22 is closed by the cap 34 leaving a space 35 into which carbon dioxide can be led through the channel 36 in the wall of the cylinder 22. The channel 36 is connected to the pipe line 37 including a pump 37a adapted to supply carbon dioxide through the line 37 at a predetermined maximum pressure. The line 37 is controlled by the non-return valve 38 and the orifice 38a which keeps to a low value the rate at which carbon dioxide can be supplied to the space 35.

The cylinder 22 extends to the outside of the biologica shield so that the cap 34 can be screwed into position and subsequently adjusted if necessary from outside the biological shield. The cap 34 is provided with a bore 39 in which the piston 40 can slide. A seal 40a is provided between the piston 40 and the bore 39. The outer periphery of the piston 40 is circumferentially notched at 41. The inner face of each notch 41 is perpendicular to the axis of the piston 40 and the outer face is inclined. A spring 42 is included between the outer end of the piston 40 and the end 43 of the cap, the end 43 being provided with a vent 44. Diametrically opposite bores 45 are also provided in the cap 34. A reciprocable stub 46 is inserted into each of the bores 45. The inner ends of the stubs 46 are provided with notches 47 co-operating with the notches 41 and are urged towards the piston 40 by the springs 49 abutting at their outer ends against the screw plugs 50. When the reactor is cold, the cap 34 is screwed into position over the O-ring seal 34a with the components 46, 49 and 50 removed until co-operation between the pistons 24 and 40 causes the piston 40 to be depressed into bore 39, i.e. in the position in which it is shown in Figure 3. In this position, the cap 34 through its piston 40 acts as an end stop for the piston 24. Components 46, 49 and 50 are then restored to the cap 34.

When the reactor is to be used, carbon dioxide is supplied to the space 35 at a pressure of 2,000 - 4,000 p.s.i. This pressure is maintained as the piston 24 moves inwardly relatively to the cylinder 22 as a result of the pressure vessel 1 expanding thermally during operation of the reactor more than the body 7. The piston 40 will not follow the piston 24 since the carbon dioxide pressure will exert a force greater than the spring 42. Should a leak develop, however, so that the gas pressure fails to overcome the spring 42, the piston 40 will be urged inwardly into contact with the piston 24. The stubs 46 will be pushed outwardly as a consequence of the shape of the notches 41 and 47 but will be restored by the springs 49 to engag

notches 41 nearer the outer end of the piston 40 to hold it in this inward position. To release the piston 40 when the reactor cools or the leak is repaired, components 46, 49 and 50 must, of course, be removed. A pressure sensitive alarm device 38b is connected to the line 37 to indicate when the pressure falls below a given value. Should the pressure in the space 35 drop the piston 24 will not be urged outwardly by the pressure of coolant gas within the pressure vessel 1, since it is restrained by the co-operation between the ball-headed member 30 and the boss 17. Any tendency for the coolant gas to escape is effectively prevented by the rings 25.

Details of the compensating links 16 by which the plates 15 are laterally connected together are shown in Figure 4. Each link 16 comprises a central rod 51 of mild steel having an enlargement 52 at one end through which it is connected by means of a pivot 16a (Figure 2) to a pair of brackets 20. The other end of the rod 51 is provided with a flange 53. The rod 51 is encircled by eight concentric tubes, of which every alternate tube 54 is plane-ended and the remaining tubes 55 are each provided with an inwardly projecting flange 56 on one end and an outwardly projecting flange 57 on the other. The flange 57 on the outermost tube 55 co-operates with the flange 58 on a cap 59 screwed on to a stub 60. A pivot 16a (Figure 2) passes through this stub 60 to connect it to a pair of brackets 20 on a plate 15 adjacent to that to which the enlargement 52 of the compensating link is connected. The tubes 55, as well as the rod 51, are of mild steel; the tubes 54 are of stainless steel. The lengths of the tubes 54 and 55 are such that the difference between the expansion of the periphery of the body 7 and the expansion of the plates 15 between the points at which the links 16 are connected to them is just equal to the expansion of the links 16.

To fix the link 16 in position, the enlargement 52 is connected by a pivot 16a to one plate 15, the stub 60 is connected by a pivot 16a to an adjacent plate 15 and the cap 59 is then screwed into position to apply the appropriate strains to the rod 51 and the tubes 54 and 55. It will be realised that the rod 51 and the tubes 55 are under tension and the tubes 54 are under compression.

Control rods are guided into the control rod channels 11 through the control rod guide tubes 61 (Figure 1) which terminate at a height above the top plate 14 which is just sufficient to prevent the tubes 61 and the plate 14 from coming into contact as a result of expansion due to the heat developed in the reactor during use. The tubes 61 pass through stand pipes 61a welded to the thermal sleeves 62 in the top of the pressure vessel 1 in a known way. The upper ends of the stand pipes 61a are connected to the enlarged portions 62 containing control rod

operating gear which serves to hold the guide tubes 61 in position as well as operate the control rods. The junction between each pipe 61a and enlarged portion 63 is surrounded by a muff 64 which is connected to both the pipe 61a and the portion 63. Each muff 64 lies beneath an overlapping part 65 of the biological shield 2. It will be seen that should the vessel and reactor become inverted, the plate 14 will rest upon the normally lowermost ends of the guide tubes 61 and so support the body 7. The tubes 61 will be prevented from sliding through the roof of the biological shield 2. They are maintained in position by the portions 62 and the portions 62 are held in position by the muffs 64 resting upon the overhanging portions 65 of the biological shield 2.

It will be seen that in the embodiment described the body 7 is properly supported in all the conditions that are likely to arise. During normal conditions it is supported from below by the diagrid 8 and is constrained during thermal expansion by the compensated sectionalised support wall containing the plates 15 connected together by the compensating links 16. It is prevented from moving laterally relatively to the pressure vessel 1 despite expansion of the pressure vessel 1 relatively to the body 7 by the lateral tubular support members 21. Any substantial lateral movement of the body 7 relatively to the pressure vessel 1 due to pitching or roll of the ship will be resisted by the pressure in the spaces 35 of those of the tubular support members 21 to which the body 7 tends to move. Since these spaces 35 are closed by the non-return valves 38, the carbon dioxide in them will tend to become compressed and so resist movement of the body 7 relatively to the pressure vessel 1. The spaces in the support members 21 on the side of the reactor away from which the body 7 tends to move will expand and the pumps 37a will operate to tend to restore the pressure. The rate at which the pumps 37a can operate is, however, limited by the orifices 38a and since the pitching and rolling movements of the ship are of comparatively short duration, the pressure in these spaces 35 will not be greatly in excess of the desired maximum when the ship returns to an even keel. Should the pressure in the spaces 35 fail, pistons 40 will move inwardly to maintain the piston 24 in position relatively to the cylinder 22. Even if the vessel lists seriously in emergency conditions, the body 7 will nevertheless be supported by engagement between the pistons 24 and 40. Finally, if the reactor should be completely inverted, the body 7 will be supported on the guide tubes.

An alternative form of tubular support member 21 is shown in Figure 5. In this, a simple cap 70 is screwed on to the outer end of the cylinder 22 and a spring 71 is interposed between the end of the cap 70 and the end of the piston 24. The spring 71 is under compression so that its use is analogous to the use of

fluid pressure. Alternatively the spring 71 could be under tension since the body 7 is encircled by the sectionalized support wall and the inner end of each piston 24 is connected to the support wall. The springs 71 under tension would have to be secured at their ends to the caps 70 and pistons 24 but have the advantage that they provide a force acting inwardly on the pressure vessel 1 and tending to compensate the outward force due to the pressure of carbon dioxide being circulated as a coolant. In the embodiment shown, the springs 71 are about 4' long.

In a modification of the embodiment shown, the three lateral tubular supports arranged around one half of the periphery of the body 7 could be replaced by simple fixed spacing members, relative movement between the body 7 and the pressure vessel 1 being compensated for by the remaining three tubular support members 21. If the body 7 merely rests against the fixed spacing members, it is necessary that the pistons 24 should be urged inwardly relatively to the cylinders either by gas pressure or springs 71 under compression; springs under tension would tend to pull the body 7 away from the fixed spacing members unless the body were fixed to them.

The claims defining the invention are as follows:-

1. A nuclear reactor of the kind having a core disposed within a closed vessel and including a body of moderating material formed with fuel channels and having a bottom support, wherein lateral supports are arranged to position the body laterally within the vessel, the lateral supports acting between the body and the vessel and being adapted to permit differential thermal expansion and contraction between the body and the vessel. (4th September, 1957).

2. A nuclear reactor as claimed in Claim 1, wherein the fuel channels are upright and the body is constrained at its sides by a circumferentially sectionalized support wall surrounding the body, adjacent sections of the wall are coupled together by compensating means adapted to ensure that the constraining action of the wall on the body is maintained despite differential thermal expansion and contraction of the body, and the wall and the lateral supports act on the body through the support wall. (4th September, 1957).

3. A nuclear reactor as claimed in Claim 2, wherein the body is of polygonal cross-section, the sections of the support wall each include two parts set at an angle to each other and each engaging one of two adjacent faces of the body and the lateral supports each act on the junction between the two parts. (4th September, 1957).

4. A nuclear reactor as claimed in Claim 3, wherein the number of sections is equal to one half the number of faces. (4th September, 1957).

5. A nuclear reactor as claimed in any one of Claims 2 to 4, wherein the support wall includes two or more portions disposed one above the other and each surrounding the body, each portion being provided with a set of lateral supports. (4th September, 1957).

6. A nuclear reactor as claimed in any one of Claims 2 to 5, in which the compensating means are in the form of links each connected between two adjacent sections of the support wall and each link comprises a central member surrounded by an even number of concentric tubes, one end of the central member being connected to one section of the wall and the opposite end of the outermost tube being connected to an adjacent section of the wall, every alternate tube, including the outermost, and the central member being formed of mild steel and being under tension, the remaining tubes being of stainless steel and being under compression exerted by an inwardly directed flange at one end of the next outermost tube and an outwardly directed flange at the opposite end of the next innermost tube, or the central member. (4th September, 1957).

7. A nuclear reactor as claimed in the preceding claim, wherein means is provided for maintaining the body in position in the vessel when the vessel is inverted. (4th September, 1957).

8. A nuclear reactor as claimed in Claim 7, wherein the means provided for maintaining the body in position in the vessel when the vessel is inverted include control rod guide tubes secured to the normally upper end part of the vessel and arranged to support the inverted body through grid or plate means located at the normally upper end of the body. (4th September, 1957).

9. A nuclear reactor as claimed in any preceding Claim, in which the reactor includes a biological shield and the pressure vessel is supported from the biological shield by upper and lower supporting means of which the lower supporting means are adjacent to supports on the interior of the vessel for the grid or platform for supporting the said body. (4th September, 1957).

10. A nuclear reactor as claimed in any

preceding Claim, in which each lateral support comprises a component associated with the pressure vessel, a component associated with the core and resilient means under compression acting between the components. (4th September, 1957).

11. A nuclear reactor as claimed in Claim 10, in which the resilient means under compression is a fluid. (4th September, 1957).

12. A nuclear reactor as claimed in Claim 10, in which the resilient means under compression is a spring. (4th September, 1957).

13. A nuclear reactor as claimed in any one of Claims 1 to 9, in which each lateral support comprises a component associated with the pressure vessel, a component associated with the core and resilient means under tension acting between the components. (4th September, 1957).

14. A nuclear reactor as claimed in any preceding Claim, in which each lateral support member includes a tubular member welded at its inner end to the periphery of an aperture in the pressure vessel and a further member, the further member being movable longitudinally within the tubular member and acting between the body and the tubular member. (4th September, 1957).

15. A nuclear reactor as claimed in Claim 14 and provided with a biological shield, in which the tubular member extends outwardly of the biological shield and the outer end of the tubular member is provided with a backing-up member that can be adjusted from outside the biological shield to limit the movement of the further member outwardly relatively to the tubular member. (4th September, 1957).

16. A nuclear reactor as claimed in any one of Claims 1 to 9, in which each lateral support includes a tubular member welded at its inner end to the periphery of an aperture in the pressure vessel and a piston movable within the tubular member and acting at its inner end on the body and fluid pressure is provided to urge the piston inwardly relatively to the tubular member. (4th September, 1957).

17. A nuclear reactor as claimed in Claim 16 and provided with a biological shield, in which the tubular member extends outwardly of the biological shield and the outer end of the tubular member is provided with a backing-up member that can be adjusted from outside the biological shield to

limit the movement of the piston outwardly relatively to the tubular member. (4th September, 1957).

18. A nuclear reactor as claimed in either of Claims 16 and 17, in which means responsive to failure of the fluid pressure is provided to maintain the tubular member and the piston in the relative position which they occupy on failure of the fluid pressure. (4th September, 1957).

19. A nuclear reactor as claimed in Claim 18 when appendent to Claim 17, in which the inner end of the piston is fixed relatively to the body, and the backing-up member includes a further piston urged towards engagement with the first-mentioned piston by spring means which are normally overcome by the fluid pressure and locking means adapted to prevent movement of the further piston in a direction opposite to that in which it is urged by the spring means. (3rd September, 1958).

20. A nuclear reactor substantially as described with reference to and as illustrated by Figures 1 to 4 of the accompanying drawings or Figures 1, 2, 4 and 5 of the accompanying drawings. (3rd September, 1958).

GRIFFITH, HASSEL & FRAZER.
Patent Attorneys for Applicant.

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References:

Serial No.	Application No.	Classification.
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223,415	33,216/57	07.8.

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FIG. 2.

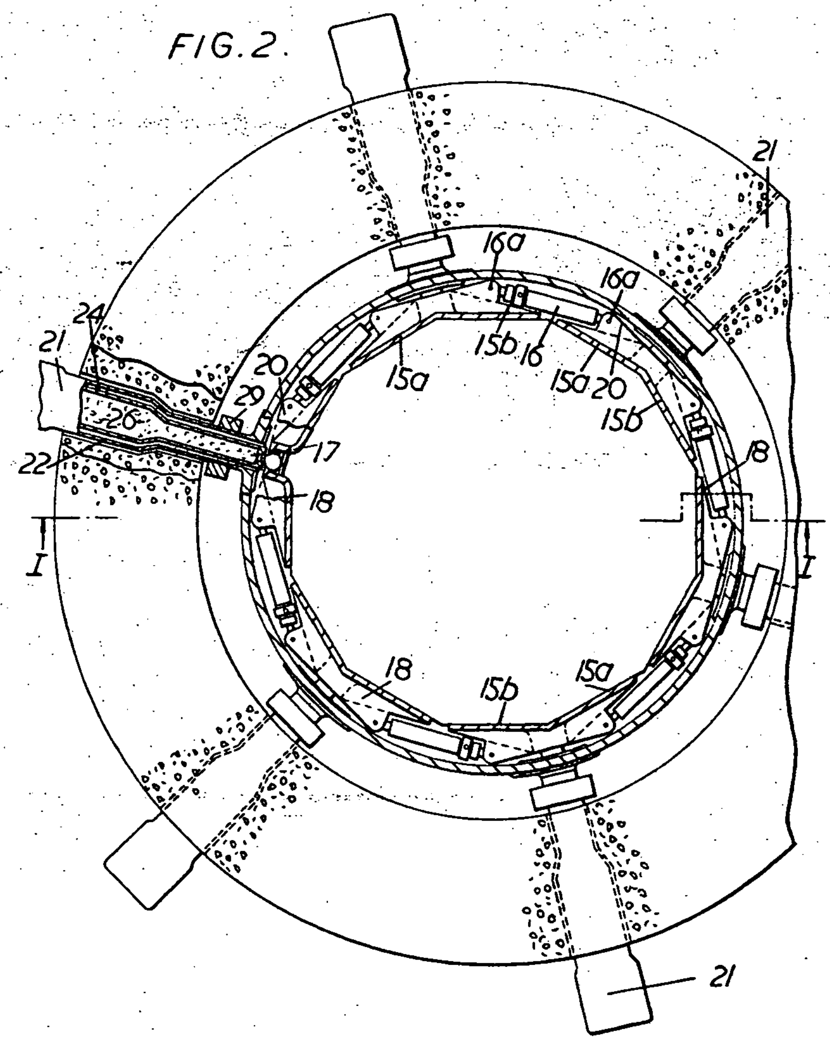

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FIG.1.

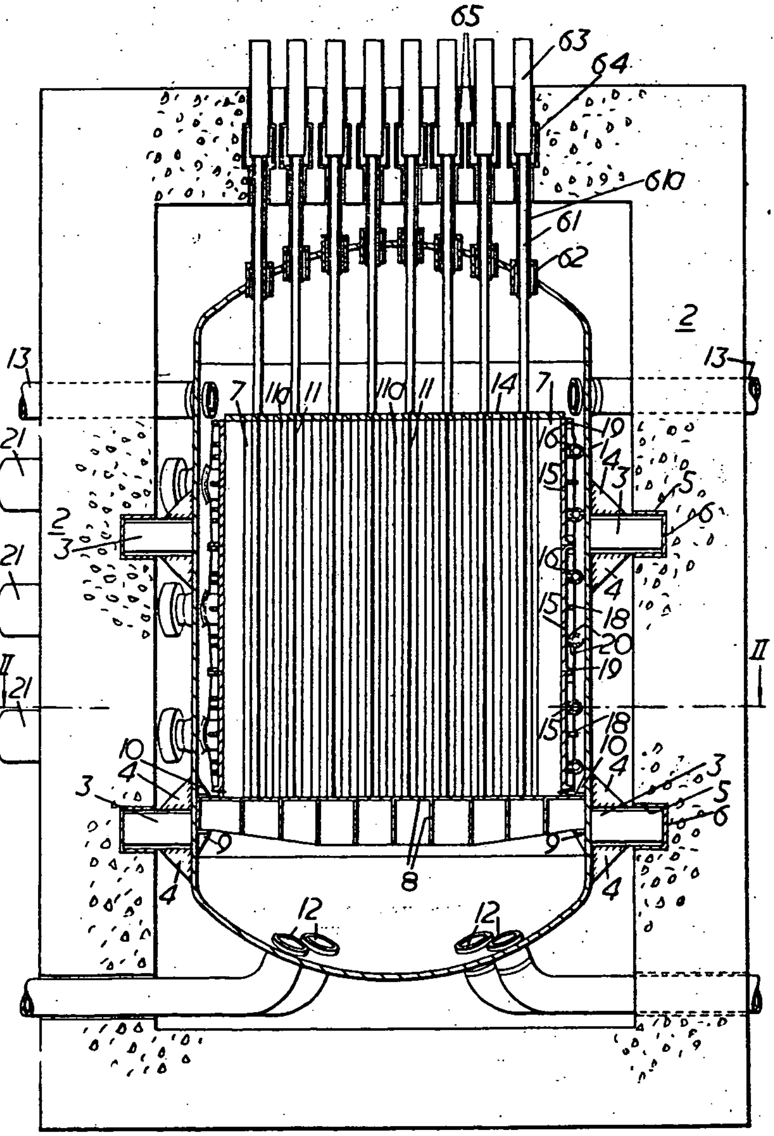

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FIG. 4.

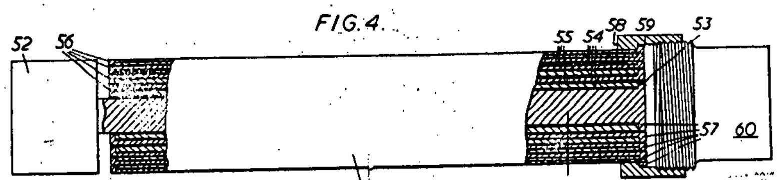

FIG. 3.

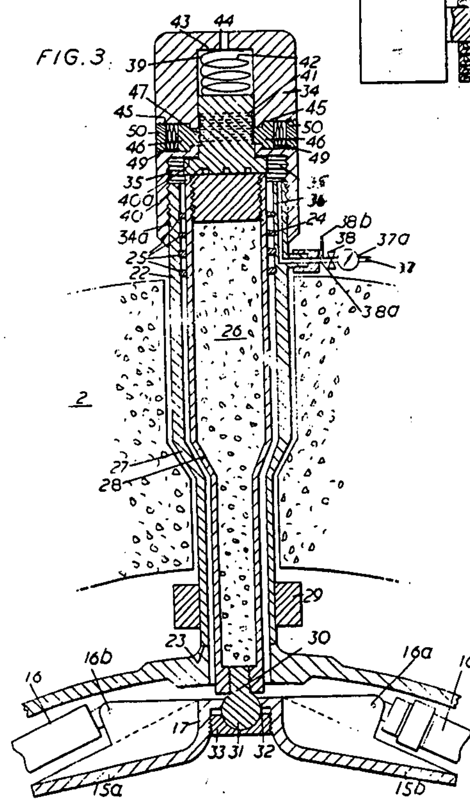

Fig. 5